FCF Requirements and Verification

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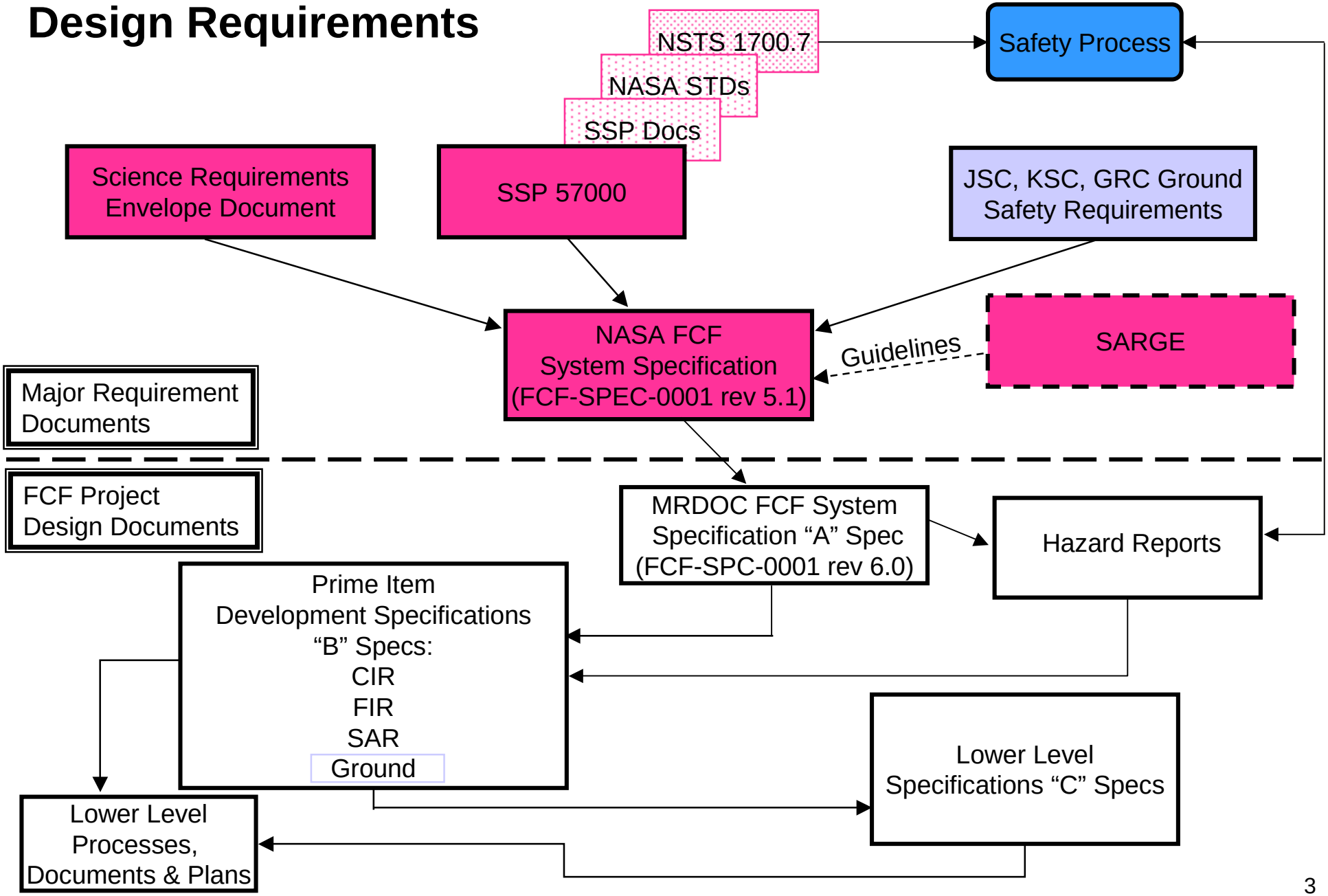
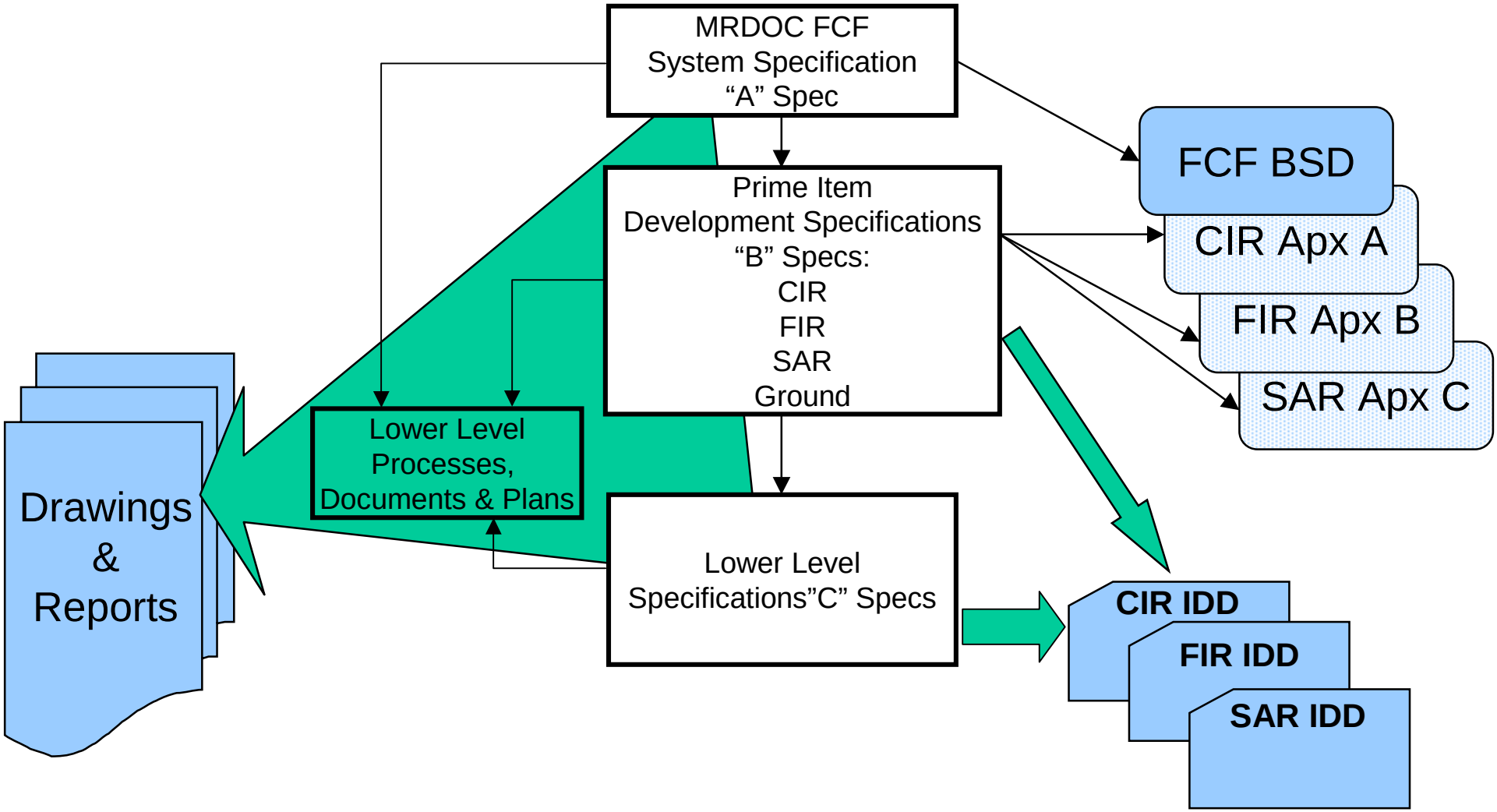
FCF Requirements and Verification

- Design requirements
- Design documentation
- Requirements traceability flow
- Requirements compliance
- Verification Documentation
- Experiment Verification
- On-Orbit Verification

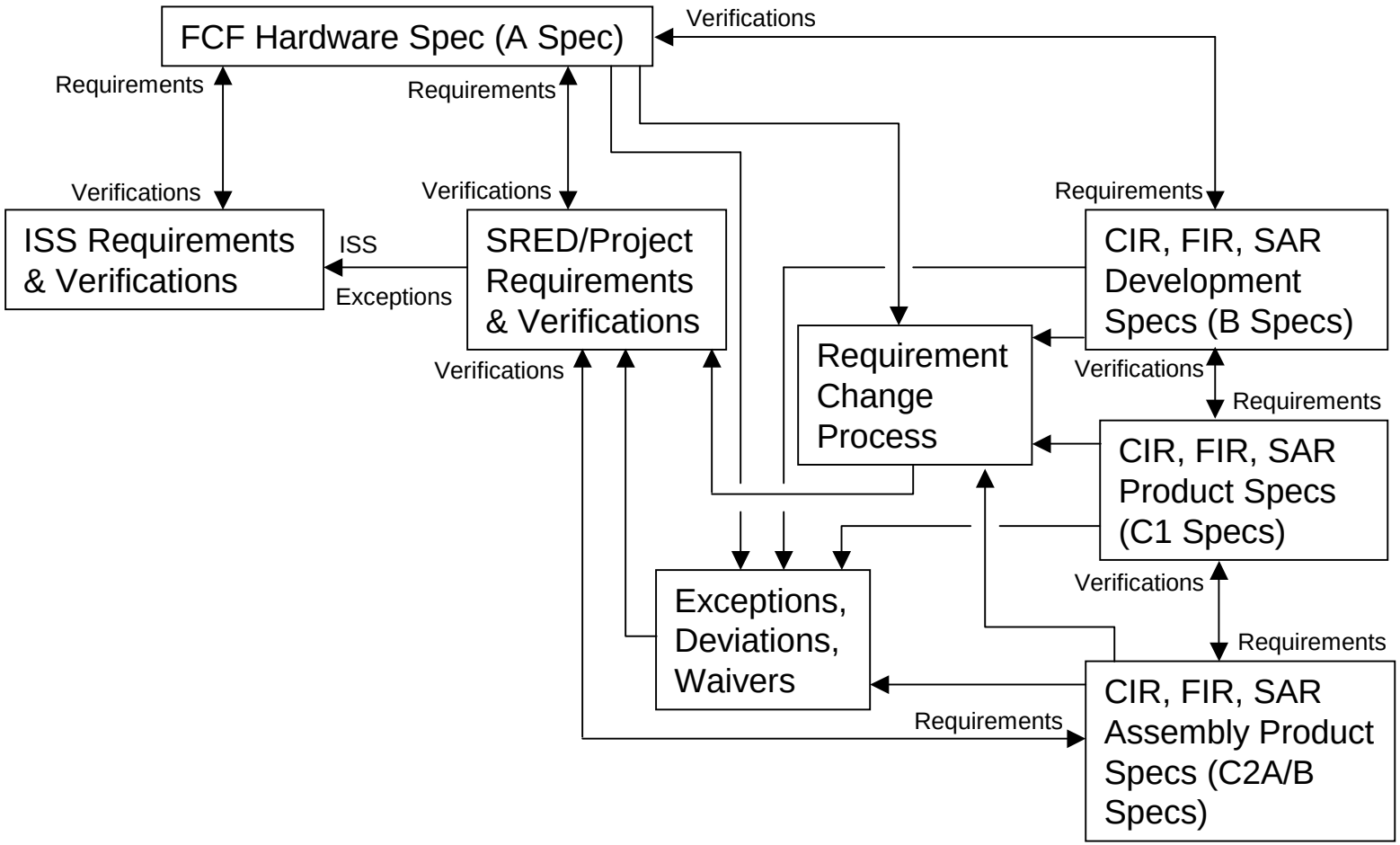
Design Requirements



Design Documentation



FCF Requirements and Verifications Traceability Flow



Example of DOORS Flow Down to Lower Level Documents

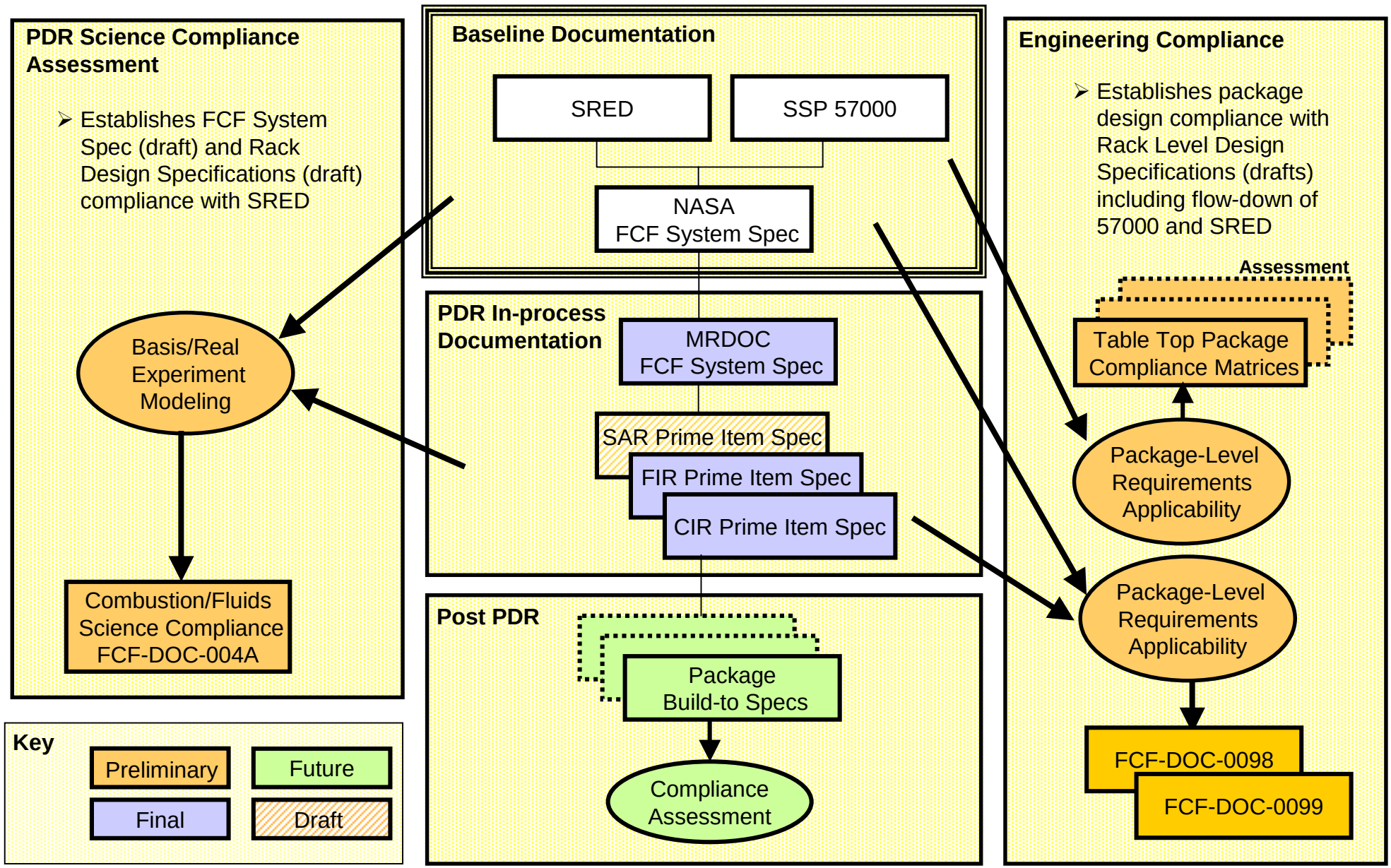
System Specification Draft 6.0 - July 2000	Verification Method	Compliance Level
3.2.1.1.7 Capability: Accept and respond to inputs and commands.		
a. The FCF Flight Segment shall accept, validate, acknowledge, and respond to inputs and commands from the on-orbit crew a command was received and the command identifier.	Test	Comply
b. The FCF Flight Segment shall accept, validate, acknowledge, and respond to commands generated by the ISS, the FCF Ground Operations Team, and Payload Equipment Teams, including an indication that a command was received and the command identifier.	Test Inspection	Comply
c. The FCF Flight Segment shall use the SSC for the on-orbit crew to control the Flight Segment.	Test Inspection	Comply
3.2.1.1.8 Capability: Maintenance/troubleshooting.		
a. The Flight Segment and FSSS shall allow the on-orbit crew the FCF Ground, Operations Team and Payload Equipment Teams to troubleshoot the cause of out-of-tolerance conditions, including failures, and isolate the cause down to an Orbital Replacement Unit (ORU) level.	Test Inspection	Comply
b. The FCF System shall provide for the maintenance of the Flight Segment to keep it within the performance parameters specified within this document, for maintenance/replacement of limited life items, and for the replacement of ORU's that have failed or are operating in an out-of-tolerance condition.	Inspection	Comply
c. Each Flight Segment rack shall be capable of being reconfigured without impacting the operations of the other racks, except for possible microgravity disturbances.	Analysis	Comply
d. The Flight Segment shall have the means to re-verify instruments that remain on orbit to determine precision and accuracy. This re-verification is	Analysis Test	Comply

The CIR, with applicable PI ha...

/FCF/Reqs/FCF-SPC-0002

/FCF/Reqs/FCF-SPC-0005

FCF PDR Requirements Compliance Assessment



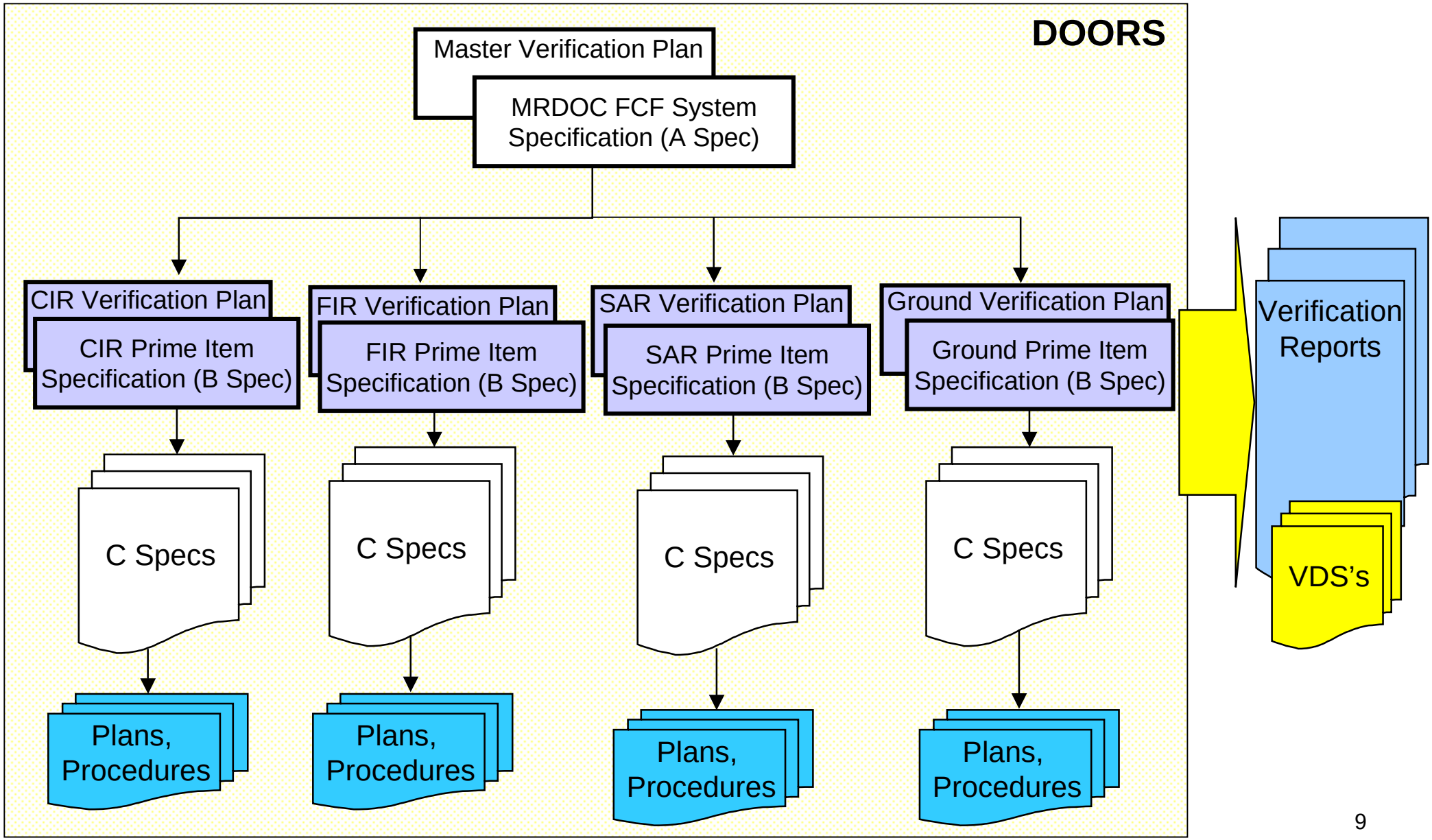
FCF System Requirements Compliance

	Number of Applicable Requirements	Comply	Non-Comply	Will Comply
ISS Requirements				
CIR	288	285	0	3
FIR	288	288	0	1
SAR	287	287	0	1
FCF-SPEC-0001 Requirements				
System	220	184	4	32
CIR	91	78	0	13
FIR	86	54	0	32
SAR	51	49	0	2
Ground	60	4	0	56
SRED Requirements				
“P” Requirements	20 *	18	0	0
“F” Requirements w/ PI H/W	45	38	0	7
“C” Requirements w/ PI H/W	20	17	2	1
“O” Requirements	16	8	1	7

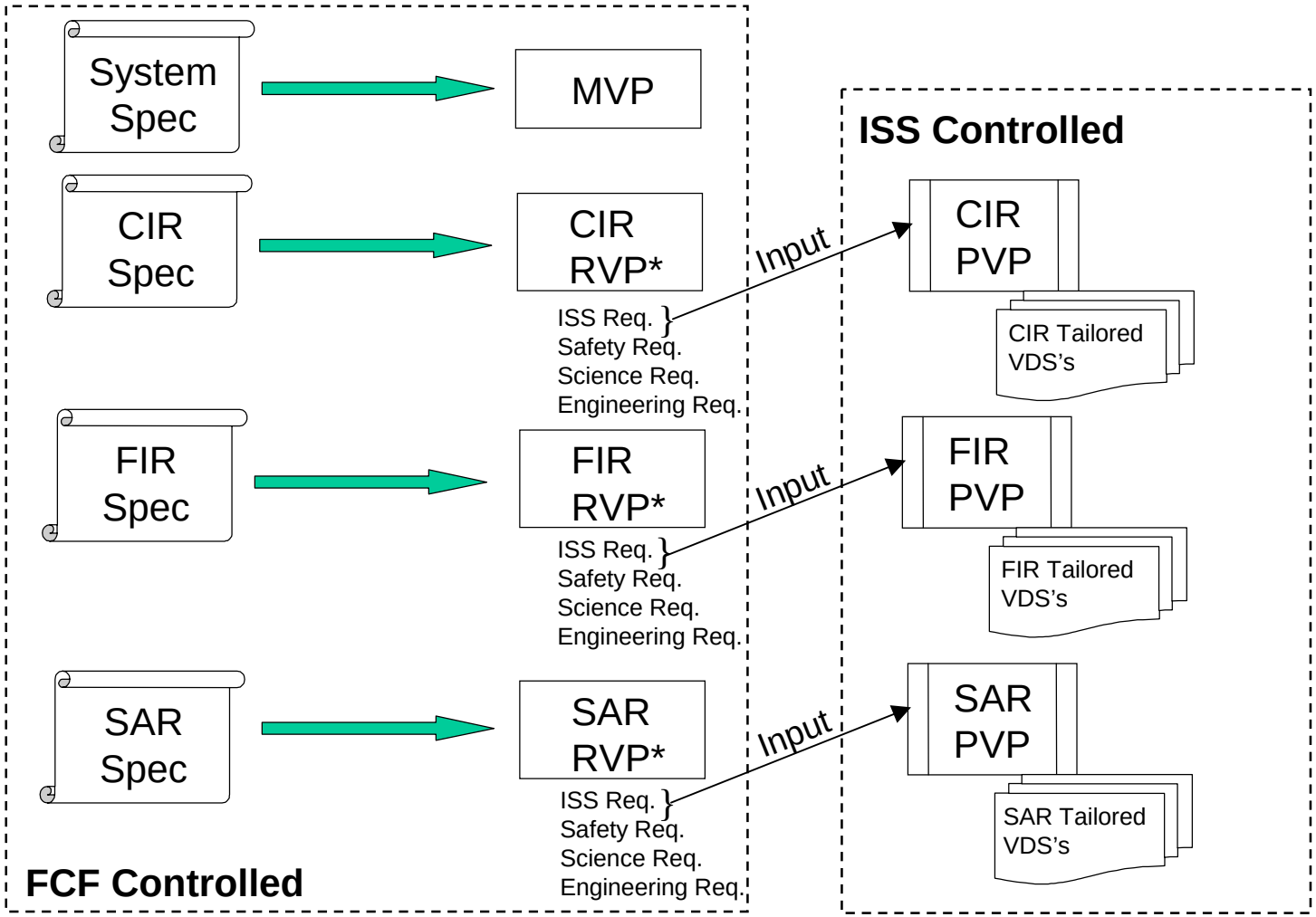
*2 of these requirements are not on FCF.

Will comply indicates that the current compliance is not known, but compliance is expected when sufficient analyses/test are performed to verify estimates or design improvements are implemented.

Verification Documentation



Verification Documentation and Relationships



*Requirements Verification Plan is used to distinguish between the MRDOC plan and the ISS Payload Verification Plan for FCF payloads.

Verification

- Verification will be conducted at multiple levels by Test, Analysis, Inspection, and Demonstration
- Top level verifications may combine testing and analysis from lower levels into a system analysis
- FCF System Verifications
  - Ground Integration Unit (GIU), Telescience Support Center (TSC) interfaces, Ground Support Equipment (GSE), Payload Rack Checkout Unit (PRCU), and Flight Racks working together

Verification – Continued

- ISS Requirements Verifications
  - Primarily verified at Rack level and Orbital Replacement Unit (ORU) level
    - Sharp edges, structural, crew interfaces, etc. – Both
    - Electromagnetic interference (EMI), noise, water, thermal, etc. – Rack level
  - Few at System level
    - Rack umbilical

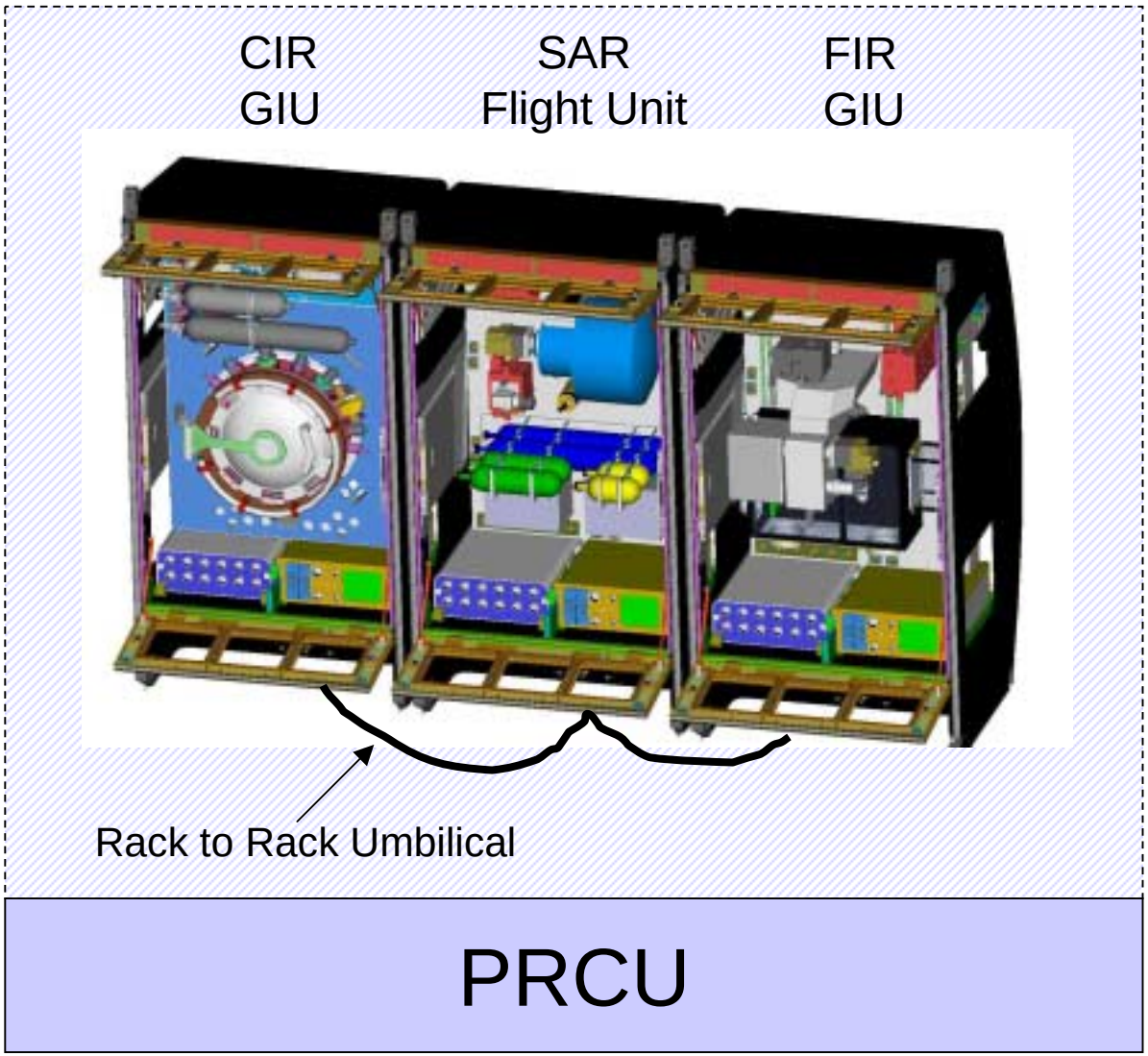
Verification – Continued

- System Specification Requirements Verifications (Flight)
  - Primarily verified at Rack level (CIR, FIR, SAR)
    - Most Combustion and Fluids Science requirements
  - Few at System level and Rack
    - System throughput
    - Power, data rate, crew time, energy, water, N2, respond to out of tolerance conditions
    - Areas where SAR and CIR or FIR cooperate
      - Data storage and downlink, control

Verification – Continued

- System Specification Requirements Verifications (Ground)
  - Rack level verifications
    - Ground Integration Unit (GIU) and Experiment Development Unit (EDU) similar to flight verification functionally
  - Ground Support Equipment (GSE) verifications
    - Separate units (support stands)
    - Systems (chillers, power supplies)
  - Total Ground System
    - GIU with GSE and Telescience Support Center (TSC)

Use of PRCU and GIU to Interface with Flight Racks for Integrated Testing

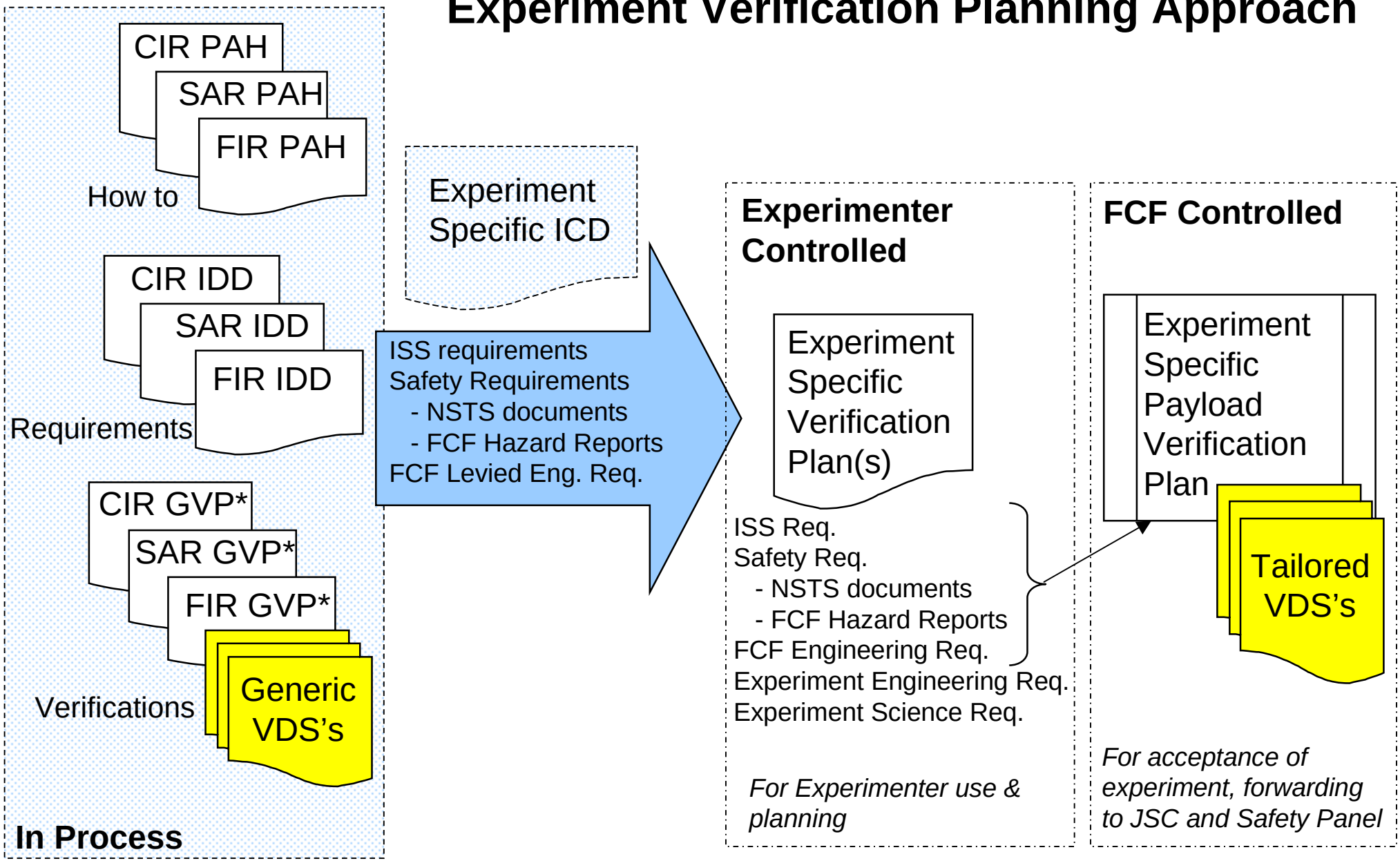


Verification of Racks

	Flight Level Environmental Testing*	Qualification Tests*	Functional Tests#	Special Ground Testing# (facility safety requirements)
Flight Units	Applicable	N/A	Flight testing	N/A
EM/EDU	Except for Vibration and Thermal same as flight	Vibration and Thermal (See EM test Plans)	Same as flight tests	May be required
GIU	N/A	N/A	Same as flight tests	May be required
PTCU	N/A	N/A	Tests for training function	Applicable

*Note that testing is done at package level
#Note this testing may be done at either package and/or rack level

Experiment Verification Planning Approach



*Generic Verification Plans for FCF Payloads

Experiment to FCF Requirement Example

Generic IDD Requirement

3.4.3 Chamber Insert Assembly Mounting to Chamber

- The Chamber Insert Assembly (CIA) mounts to the chamber using four rails, made of 440C stainless steel, located inside the chamber. Two sets of two rails are provided positioned 22.5° above and below the horizontal axis of the chamber.
- Rail parallelism is kept within 0.1 m from the front to the back of the chamber. Accuracy for CIA centering with respect to the center of the chamber is +/- 0.13 m.

Product Item Specification ("C" Spec) Requirements for Chamber

3.2.1.1 Rail Positioning

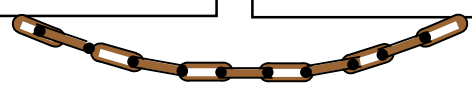
a. One chamber rail shall be positioned at 22.5° above the horizontal axis of the chamber on the right side.
b. A second chamber rail shall be positioned at 22.5° above the horizontal axis of the chamber on the left side.
c. One chamber rail shall be positioned at 22.5° below the horizontal axis of the chamber on the right side.
d. A second chamber rail shall be positioned at 22.5° below the horizontal axis of the chamber on the left side.

3.2.1.2 Rail Material

- The rail material shall be 440C stainless for all four rails.

3.2.1.3 Rail Parallelism

- Rail parallelism must be within 0.1 m from the front to the back of the chamber.



DOORS Linkage

Verified once

On-Orbit Verification

More than four types of on-orbit verification

- Initial verification when arrive on orbit
- Acceptance verification (Initial Principal Investigator (PI) hardware)
- Calibration/safety verifications
- After repair/replacement/reconfiguration

On-Orbit Verification – Continued

Initial on-orbit verification

- This verification will check out most rack functions
  - Electrical Power Control Unit (EPCU) power up and commanding
  - Communications
    - Each rack with ISS & ground (Downlink & uplink)
    - FCF System at assembly complete communication between racks
  - Fuel/Oxidizer Management Assembly (FOMA) test (fill, leak check, vent, etc.)
  - Air Thermal Control Unit (ATCU)/Water Thermal Control System (WTCS)
  - Software functions
  - Optical/Diagnostics
  - Assumed that Active Rack Isolation System (ARIS) verifications are ISS responsibility
- Includes nominal and off-nominal modes

On-Orbit Verification – Continued

Initial on-orbit verification specifics Diagnostics example:

- Verify alignment of diagnostics for all windows. This will include linear (x, y, z) alignment with the chamber axis (boresight).
- Orthogonality of views will require verification. Out of tolerance measurement will be useful.
- Verify illumination source quality?
- Field of view verification.
- Camera focus.
- Window optical characteristics, such as optical properties and damage.
- Wavelength of illumination sources.
- Transmission properties of filters.
- Resolution of cameras.
- Depth of field of cameras (aperture).
- Verification/calibration of Fuel/Oxidizer Manifold Assembly (FOMA) functions and sensors including temperature and pressure measurement devices as well as mass flow controllers in each manifold.

On-Orbit Verification – Continued

Acceptance verification (Initial PI hardware)

- CIR operates with Multi-User Droplet Combustion Assembly (MDCA)
- FIR operates with Light Microscopy Module (LMM)
- SAR operates with TBD (Most likely will be a fluids experiment)

On-Orbit Verification – Continued

Calibration/safety verifications

- On-Orbit Leak Integrity Check (OLIC)
- Pressure Transducers
- Calibration Chamber Insert Assembly (CIA) incorporating pressure and temperature sources calibrated to National Institute of Standards and Technology (NIST) standard
- Optical targets required for diagnostic verification
- Avionics required to support the insert

On-Orbit Verification – Continued

After repair/replacement/reconfiguration

- BIT on software driven components
- Communication
- Other verifications similar to initial rack start up specific to the item replaced and its interfaces